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Atomic Weight of Silver Redetermined

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DETROIT

A NEW value of the atomic weight of silver—a key element in determining atomic weights of other elements—has been obtained by the National Bureau of Standards with the cooperation of the Atomic Energy Commission. The new value results directly from a highly accurate determination of the absolute isotopic abundance ratio¹ of silver using the techniques of mass spectrometry. This determination was carried out by W. R. Shields and Dr. V. H. Dibeler of the mass spectrometry laboratory and Dr. D. N. Craig of the electrochemistry laboratory.

The work on the atomic weight of silver was part of a broad program the purpose of which is to obtain more accurate values of fundamental constants in order to meet the continuing demands of science and industry for more precise measurements. Besides its use in establishing the atomic weights of other elements, the atomic weight of silver plays an important part in the assignment of values to other fundamental constants, such as Avogadro's number, the faraday, and the gas constant. Redetermination of the faraday² was the principal reason this research on silver was initiated.

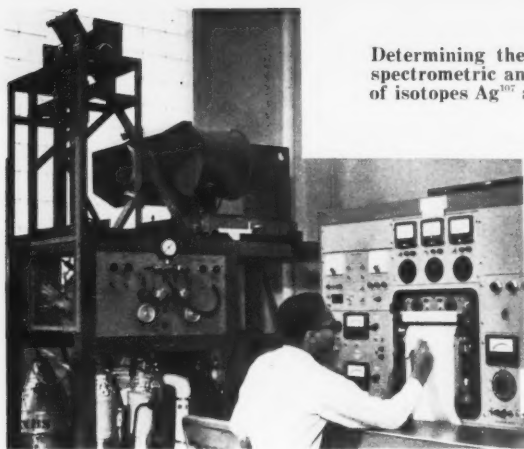
Natural silver consists of two isotopes of approximately equal abundance: Ag^{107} and Ag^{109} . Although the mass of each isotope is known in relative atomic units, until recently the isotopic abundance ratio ($\text{Ag}^{107}/\text{Ag}^{109}$) had not been

measured accurately—that is, by using synthetic mixtures of silver isotopes as calibration samples. The abundance ratio of the two silver isotopes had been determined at other laboratories, but substantial differences had been reported in the values obtained.

In general, the mass spectrometer will indicate slightly higher concentrations of one isotope than another, even though both isotopes may be present to the same extent. For this reason, it was necessary first of all to determine the instrumental bias. This bias was measured by calibrating the instrument with pure silver samples especially prepared to contain known abundance ratios of the isotopes. A small but accurately measureable discrimination of approximately 0.5 percent in favor of Ag^{107} was found.

Procedure

Once the mass spectrometer bias had been measured, the absolute isotopic abundance ratio of naturally occurring silver could be accurately determined. This ratio was measured for reference silver nitrate and for native silver from various parts of the world. The variation among these samples was found to be insignificant, with one exception. From this isotopic ratio of the reference silver, corrected for the observed bias, the absolute atomic weight of silver was computed as



Determining the absolute isotopic abundance ratio of silver by mass spectrometric analysis. E. L. Garner studies data showing the amount of isotopes Ag^{107} and Ag^{109} present in a silver sample.

107.8731 \pm 0.0018 on the chemical scale.³ This figure differs significantly from the internationally accepted chemical value of 107.880.

The mass spectrometer used for these experiments is a single-focusing, surface-emission instrument having a 12-in. radius-of-curvature and 60° deflection. Rhenium is used in the triple-filament source⁴ for all the sample filaments as well as for the source of ions. As in similar cases, this metal is used as a compromise of work function and high melting point to obtain the best yield of silver ions.

Separated silver isotopes were obtained from AEC's Oak Ridge National Laboratory for use as calibration samples. Five synthetic blends of silver were prepared with isotope ratios near that of naturally occurring silver. Although the total impurity content of other elements detectable in the original isotopes by spectrochemical analysis was less than 0.01 percent, the metal used in two of these mixtures was further purified by electrodeposition. No difference was noted between results with the more highly purified samples and the others. Weighed portions of each isotope were dissolved together in nitric acid to form a homogeneous mixture and then evaporated to dryness. Extreme care was taken to prevent contamination and chemical discrimination.

After the 107/109 ratio of each synthetic mixture had been calculated from the known weights of Ag^{107} and Ag^{109} , the mixtures were analyzed in the mass spectrometer. This is done by dissolving silver in nitric acid solution and depositing the resulting silver nitrate on the sample filament of the spectrometer. The deposited sample was then reconverted into metallic silver by electrically heating in a hydrogen atmosphere.

Instrumental Discrimination

In each case, the spectrometer consistently gave a slightly higher ratio than the calculated value, indicating that the spectrometer discriminates in

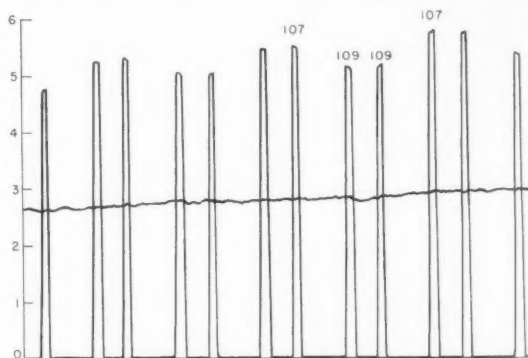
favor of the Ag^{107} isotope. The discrepancy is of the order of magnitude expected for thermal separation of the isotopes based on the square root of the ratio of the isotopic masses.

To determine whether naturally occurring silver from widely scattered localities has identical isotopic compositions—and thus the same atomic weight—samples of natural silver were obtained from Arizona, Michigan, Montana, Canada, Honduras, Mexico, and Norway. In preparation for the measurements, these silvers were converted into silver nitrate solution. The isotopic abundances of the silver from these samples were measured in the mass spectrometer and then compared with the value obtained for a commercial silver nitrate sample. This material, adopted as a reference sample for the experiment, was used as a control.

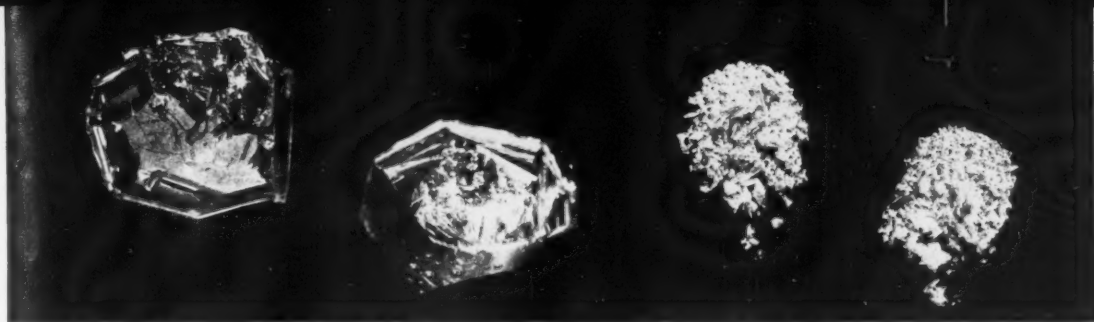
In general, the isotopic compositions of all the silvers except the one from Canada were indistinguishable from that of the reference sample. Because the abundance of the Canadian silver was slightly, but significantly different, additional samples from the same region are now being studied.

Atomic Weights

The $\text{Ag}^{107}/\text{Ag}^{109}$ ratio, 1.07547 \pm 0.0013, is obtained by correcting the ratio of the reference silver nitrate for the measured degree of instrumental bias. This corrected abundance ratio multiplied by accurate values of the nuclidic masses—which were measured in a mass spectrometer by Dr. A. O. Nier and coworkers at the University of Minnesota—results in an atomic weight for silver on the physical scale⁵ of



Typical mass spectrometric data for silver, showing the continual recording of Ag^{107} and Ag^{109} . The abscissa corresponds to the mass of silver and the ordinate to the abundance. The continuous, nearly horizontal line is an indication of the total ion current of both isotopes and is used to monitor the overall operating conditions of the instrument.



The nearly pure silver isotopes in two of the five blends used in determining the isotopic abundance ratio were further chemically purified by electrodeposition. The small piles at right are silver crystals obtained from this purification (Ag^{107} left, Ag^{109} right). To insure homogeneity, the crystals were vacuum-fused into buttons, as in the left half of the picture (Ag^{107} left, Ag^{109} right).

107.9028 \pm 0.0011. If, in conformity with the practice of the Commission on Atomic Weights, the factor 1.000275 is used to convert to the chemical scale, 107.8731 \pm 0.0018 is obtained for the atomic weight of silver.⁵ The increase in the uncertainty results from an additional variance in the conversion factor.

The uncertainty in the present physical determination of the atomic weight of silver is estimated from the degree of variance and limit of error of bias for several thousand sample determinations. It is nearly an order of magnitude less than that previously reported⁶ for mass-spectrometric measurements.

¹ Absolute isotopic abundance ratio and the atomic weight of silver, W. R. Shields, D. N. Craig, V. H. Dibeler. (In press.)

² Improved value for the faraday by new experimental process, *NBS Tech. News Bul.* 44, 34 (1969).

³ The chemical scale is based on the value of 16 as the relative mass for the natural isotopic abundance of oxygen, whereas the physical scale is based on the value of exactly 16 for the relative mass of just one isotope, ^{16}O .

⁴ M. G. Inghram and W. A. Chupka, *Rev. Sci. Instr.* 24, 518 (1953).

⁵ The indicated uncertainty is an overall limit of error based on 95-percent confidence limits for the mean and allowances for effects of known sources of possible systematic error.

⁶ A. O. Nier, *Science* 121, 737 (1955).



BRANSCOMB CHIEF OF NEW DIVISION

THE BUREAU has established a new scientific division—Atomic Physics. Dr. Lewis M. Branscomb has been appointed chief of the new division.

Atomic Physics was created by partitioning the Atomic and Radiation Physics Division. The other half of the old division will be renamed the Radiation Physics Division, and L. S. Taylor will continue as its chief.

Major areas of research in the new division include precise determination of atomic constants and other physical properties associated with free electrons, atoms, ions, and molecules; quantitative studies of the microscopic, mutual interactions of ions, atoms, molecules, and their consti-

tuent particles; and studies of the solid state, particularly of semiconductors.

Dr. Branscomb was born in Asheville, N.C., in 1926. He graduated from Duke University in 1945, and received his M.A. and Ph.D. in physics from Harvard University in 1947 and 1949, respectively. From 1949 to 1951, he was a Junior Fellow of the Harvard University Society of Fellows, and in 1951 he joined the Bureau's Physical Electronics Section. Dr. Branscomb was named chief of the NBS Atomic Physics Section in the old Atomic and Radiation Physics Division in 1956, and held that position until his latest appointment.

In 1957, Dr. Branscomb received a Rockefeller Public Service Award and was in residence for the year at University College, London; in 1959 he received an award for "outstanding scientific achievement" from the Washington Academy of Sciences.

Dr. Branscomb is a fellow of the American Physical Society and vice-chairman of its Division of Electron Physics, and a member of the American Astronomical Society, the American Geophysical Union, the Philosophical Society of Washington, and the Washington Academy of Sciences.

Cathodic Protection of Steel in a High-Resistivity Environment

A POTENTIAL of -0.77 v, previously shown to protect steel cathodically against corrosion in low-resistivity environments,¹ also afforded the highest degree of protection in a high-resistivity soil, according to a recent Bureau experiment. This potential, referred to a saturated calomel electrode, is equivalent to -0.85 v referred to a copper-copper sulfate electrode. In the present study it was found that the best results were achieved when IR (voltage) drop between the reference electrode and the metal, caused by the protective current, was excluded from potential measurements.²

As the underground corrosion of iron or steel is mainly an electrochemical phenomenon, the electric potential at which a metal structure should be held to prevent the destructive process is of practical importance. Insufficient potential will give inadequate protection. On the other hand, maintaining a greater potential than is needed represents wasted electric energy.

Earlier studies of cathodic protection at the Bureau were conducted with soils and water having resistivities of less than $1,000$ ohm/cm. In these environments, measured potentials were virtually free of IR drop. In high-resistivity en-

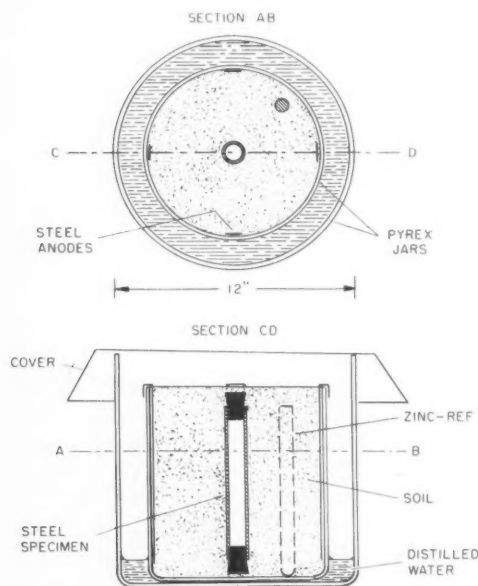
vironments, however, measured potentials made on underground structures often include considerable IR drop as well as polarization voltage. W. J. Schwerdtfeger, of the corrosion laboratory, undertook the present study to find out whether this IR drop, which under some circumstances has theoretical value, is beneficial under practical conditions, for example, in potential measurements made on pipelines. Also evaluated with respect to a high-resistivity environment were polarization techniques, formerly used successfully to determine the amount of external current necessary to give protection.

For the experiment, 5 specimens, 8-in. long, were cut from one piece of cold-drawn steel tubing (1 in. in outer diameter) and treated to confine corrosion to the outside surfaces. A sandy loam soil, having a resistivity of about $20,000$ ohm/cm, was the corrosive medium. The specimens were completely surrounded with the soil and held individually in cylindrical jars which were placed inside larger covered jars containing enough distilled water to create a saturated atmosphere. Electric connections were attached to the specimens and to a high-purity zinc rod exposed with each specimen as a reference electrode.

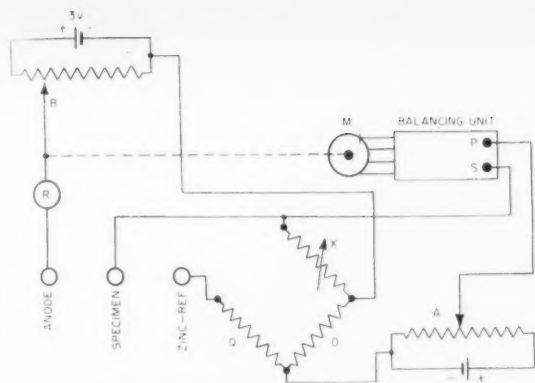
A circuit was designed for maintaining one specimen at a protective potential free of IR drop. It utilized both a bridge for balancing out the IR drop between the specimen and the zinc rod, and an electronic balancing unit for controlling the potential of the specimen. A similar circuit was employed, in conjunction with a synchronously driven voltage divider and a two-pen recorder, for automatically obtaining polarization curves on all of the specimens.

Two of the specimens were without cathodic protection, serving as controls, while the other three had currents applied during a 61-day exposure period. The current to the third specimen was adjusted in accordance with mean values of current from cathodic polarization curves obtained on the two control specimens. The potential on the fourth specimen was maintained at -0.77 v, free of IR drop, and on the fifth, at -0.77 v, including IR drop.

The current applied to the specimen held at -0.77 v, free of IR drop, was continuously recorded. Potentials between specimens and zinc electrodes, including IR drop caused by applied current, were measured almost daily, followed by measurements of the same potentials without IR drop. Finally, after potentials of the zinc rods were measured with reference to a saturated calomel electrode, the specimen potentials were converted to the saturated calomel scale and



Cross-sectional views of the experimental arrangement used for exposing a steel specimen to a low-resistivity soil.



One of the circuits used for investigating the cathodic protection of steel in high-resistivity environments. This circuit utilizes a bridge for balancing out the IR drop between the specimen and the reference electrode, as well as an electronic balancing unit for controlling the potential of the specimen.

adjustments were made, if necessary, on the control potentiometers.

An analysis of the results showed that the specimen held at -0.77 v, without IR drop, lost the least weight from corrosion during the exposure period. The other two specimens were protected to a lesser degree because of insufficient

polarization. Thus, the experiments indicate that the highest degree of cathodic protection is achieved when IR drop caused by the protective current is balanced out. In fact, the data show that IR drop included in the potential reading can be very misleading, especially in a high-resistivity soil, and that any indication of protection contributed by IR drop should be viewed with caution.

As in previous studies, it was found that cathodic polarization curves are a reliable means for measuring the current required for cathodic protection. Applied current density indicated by the break (change-in-slope) in the cathodic polarization curve agreed quite well with the actual current density found necessary to maintain polarization at -0.77 v, free of IR drop. The current required for protection was approximately three times the magnitude of the corrosion current.

¹ Potential and current requirements for the cathodic protection of steels in soils, by W. J. Schwerdtfeger and O. N. McDorman, *J. Research NBS* **47**, 104 (1951); and *Corrosion* **8**, 391 (1952); Current and potential relations for the cathodic protection of steel in salt water, by W. J. Schwerdtfeger, *J. Research NBS* **60**, 153 (1958), and *Corrosion*, **14**, 446f (1958).

² For further technical details, see Current and potential relations for the cathodic protection of steel in a high-resistivity environment, by W. J. Schwerdtfeger, *J. Research NBS* **63C**, 37 (1959).

URANIUM-PLATINUM SYSTEM

TO PROVIDE information on the alloying behavior of uranium, a study of the uranium-platinum system has recently been completed at the Bureau, in a program sponsored by the Atomic Energy Commission.¹ In order to construct a phase diagram of the two metals, J. J. Park and D. P. Finkle of the chemical metallurgy laboratory correlated data from thermal and metallographic analyses, and X-ray diffraction studies. The diagram shows that the system is characterized by 4 intermetallic compounds: UPt , UPt_2 , UPt_3 , and UPt_5 . Each compound has a different hardness and melting point. These findings, while important to the development of atomic power, may have other applications, since some of the materials decompose at relatively high temperatures.

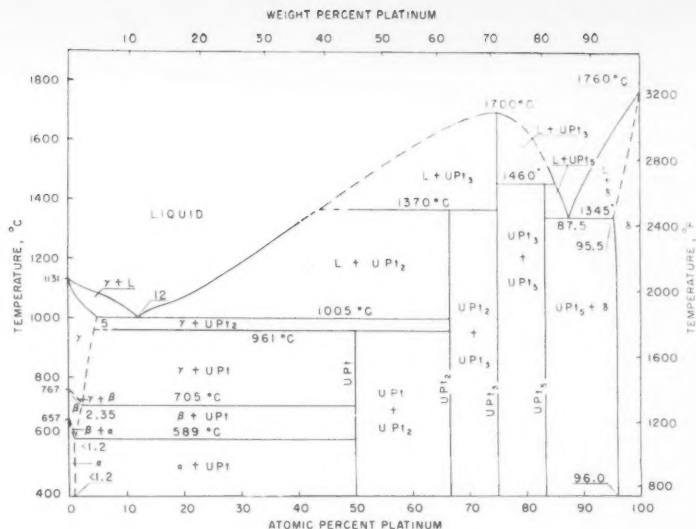
To understand and predict the properties of alloys, phase diagrams showing melting ranges, structural changes occurring at different temperatures, and solubility temperature relationships are widely used. These diagrams also assist in studying the complex reactions that result from adding other elements to an alloy. The present study is the first work in an extensive program to establish the binary phase relationships between uranium and the six platinum metals.

For the experiments, alloys varying in composition were prepared from 99.9 percent pure uranium and 99.5 percent pure platinum sponge. The sponge was compressed into small pellets before melting. Sixteen alloys with a composition ranging from 0 to 45 atomic percent (a/o) platinum were induction-melted under vacuum, and 20 alloys having 45 to 99.5 a/o platinum were prepared by arc melting under an atmosphere of helium.

To obtain the thermal analysis data, a molybdenum-wound resistance furnace was employed for specimens with liquidus temperatures up to $1,400^\circ\text{C}$; for those whose liquidus temperatures were higher, an induction furnace was used. The specimens prepared for metallographic examination and X-ray diffraction analysis were mounted in Bakelite and finished with an electrolytic polish. Microhardness tests were made to assist in identifying the constituents of the various alloys in the uranium-platinum system.

The combined data show that the UPt_3 compound has a melting point of $1,700^\circ\text{C}$ and passes directly from solid to liquid. This reaction contrasts sharply with those found for the remaining three compounds which pass from the single solid

Phase diagram constructed for the uranium-platinum system. Different compositions of the 4 intermetallic compounds which characterize the system are readily seen.



state phase to a heterogeneous mixture when heated above decomposition temperatures. The UPt_2 compound is solid up to 1,370° C, but at higher temperatures it becomes a mixture of the UPt_3 compound and a liquid. The UPt compound decomposes about 961° C; the solid decomposition products are UPt_2 and a gamma-uranium phase containing dissolved platinum. UPt_5 converts to UPt_3 and a liquid above 1,460° C.

In the experiments it was apparent that platinum dissolves in solid uranium and that uranium can be dissolved in solid platinum. Up to 5 a/o platinum can be held in the body-centered cubic

lattice of gamma-uranium; however, this dissolved platinum lowers the gamma-uranium transformation to the monoclinic beta-uranium lattice from 762° to 705° C. Similarly, the beta-uranium will hold a maximum of only 2.35 a/o platinum, which lowers the transformation to the orthorhombic alpha-uranium lattice from 660° to 589° C. The maximum amount of platinum dissolved in alpha-uranium is slightly less than 1.2 a/o, the smallest amount for the three phases of uranium. In contrast to this behavior, the amount of uranium that dissolves in platinum is fairly constant with temperature change, reaching a maximum of 4.5 a/o at 1,345° C, and decreasing to 4.0 a/o at room temperature.

Cooling point curves obtained with an electronic recorder demonstrate the effect of alloying on melting points. The addition of 12 a/o platinum to uranium lowers the melting point of uranium by more than 100° C, from 1,131° to 1,005° C. Even more drastic is the effect of uranium on platinum's melting point, which decreases from 1,760° C for the unalloyed metal to 1,345° C when 12.5 a/o uranium is added. Between 2 eutectics which occur at 1,005° and 1,345° C is the maximum melting point (1,700° C) of the UPt_3 compound.

Hardness measurements obtained for the different compounds were converted to diamond pyramid hardness, kg/mm². The values thus derived were: UPt —385; UPt_2 —905; UPt_3 —405; UPt_5 —610. Hardness values for uranium and platinum in solid solution are, respectively, 425 and 250.

Left: J. J. Park adjusts equipment used to obtain thermal analysis data for a phase diagram of the uranium-platinum system. **Right:** Mr. Park inserts a crucible containing the uranium-platinum specimen into a molybdenum-wound resistance furnace. With this apparatus, specimens are heated at temperatures up to 1,400° C.

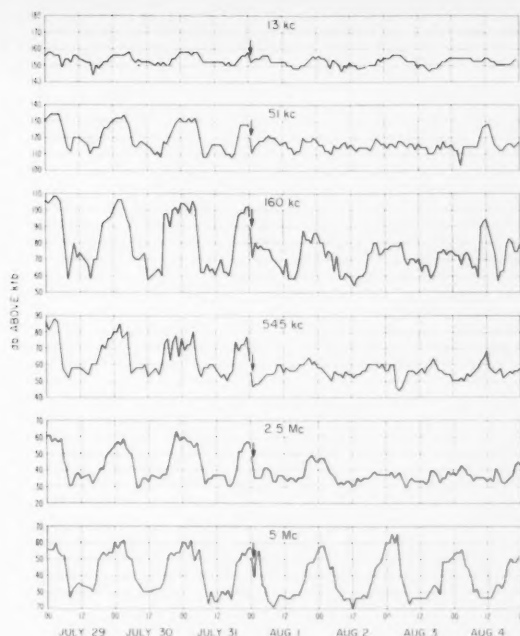


¹For further technical details, see Uranium-platinum system, by J. J. Park and D. P. Finkle, *J. Research NBS* 64A, 107 (1960).

Nuclear Tests Affect Radio Noise

THE BUREAU recorded the changes in radio noise that occurred when two high-altitude atomic explosions were set off over Johnston Island in the Pacific Ocean in August 1958.¹ The explosions appear to have had a pronounced effect on the radio noise as recorded at Kekaha, Hawaii. This recording station, located on the southwest coast of the island of Kauai, about 700 miles northeast of Johnston Island, is part of a worldwide chain of noise recording stations supervised by the Bureau's Boulder (Colo.) Laboratories.

Two bomb bursts occurred shortly after midnight on August 1 and August 12 at elevations estimated to be from 25 to 100 miles. Recordings were made of the received atmospheric radio noise power for a period before and after the first explosion. The usual diurnal pattern is evident on the graphs during the three days prior to the blast, with the highest noise levels recorded at night and a rapid decrease in level between 0400 and 0800 local time. In the hour following the blast, however, the noise decreased by as much as 32 db (at some frequencies) at a time of day when it would normally be rising or holding steady. Recovery



Graphs of radio noise power recorded at Kekaha, Hawaii, July 29-August 4, 1958. The time of the nuclear explosion on August 1 is indicated by the arrows.

apparently occurred in a matter of hours at 13 kc and 5 Mc, but from 51 kc through 2.5 Mc a changed pattern is evident for several days, and records for August 5-11 indicate that a disturbed condition persisted until the second test on August 12. The afterblast effects on this date were similar to those on August 1, with abnormal noise conditions continuing on some frequencies until about September 1.

Because of the very low incidence of thunderstorms in Hawaii, most of the received radio noise is believed to be propagated from storms at a considerable distance. Thus, changes in propagation conditions are reflected more clearly on the Kekaha noise records than at stations situated on large land masses, where local and short-distance storm effects tend to mask changes in propagation.

It would appear likely that a highly ionized region was formed by the bomb explosions over Johnston Island and that this ionized region persisted for a period of at least several days after each test, causing greatly increased ionospheric absorption.

Radio noise recording station and antenna array at Kekaha, Hawaii. This station is one of a number of worldwide noise recording stations maintained by the Bureau.



¹ For further technical information, see Effects of high-altitude nuclear explosions on radio noise, by C. A. Samson, J. Research NBS 64D, p. 37, (Jan.-Feb. 1960).



Pedestrian traffic test ramp installed in the corridor of an NBS building to test conductive flooring materials under actual traffic conditions. Each sample is 18 by 18 in.

CONDUCTIVE FLOORING FOR HOSPITAL OPERATING ROOMS

CONDUCTIVE flooring is as serviceable as non-conductive flooring of the same type, and it reduces explosion hazards, according to a recent Bureau investigation¹ sponsored jointly by the Army, Navy, and Air Force. The Bureau also found that current methods for measuring the resistance of installed conductive floors reasonably simulate the conditions these floors meet in service. The investigation was carried out by T. Boone, F. Hermach, E. MacArthur, and R. McAuliff.

Although the flooring was investigated primarily for use in hospital operating rooms, many of the results obtained should apply equally well to floors that are used in other locations such as munition plants or storage depots for explosives. Consequently, architects may now choose conductive flooring materials for all these uses, within some limitations, on the basis of the behavior of similar nonconductive materials.

Explosive vapors are often present in hospital operating rooms. If static electricity is allowed to accumulate, it can cause sparks having sufficient energy to ignite these vapors.² The most effective means for reducing this hazard is to keep the electrical resistance between objects in the area so low that the minimum sparking voltage (about 400 v) is never attained. Conductive flooring provides the necessary linkage because most objects normally rest or move upon the floor.

Electrical resistance of flooring material is generally lowered by adding carbon black which is produced by thermally decomposing acetylene gas under carefully controlled conditions. Carbon black is dispersed in the mixes that are shipped for on-the-job composition of latex, concrete terrazzo, and the setting bed for the ceramic tile. On the other hand, the carbon black is dispersed during manufacture in ceramic, linoleum, rubber, and vinyl flooring.

Testing Method

Specifications and measurements of flooring resistance are usually made according to the method recommended by the National Fire Protection Association (NFPA). According to this method,³

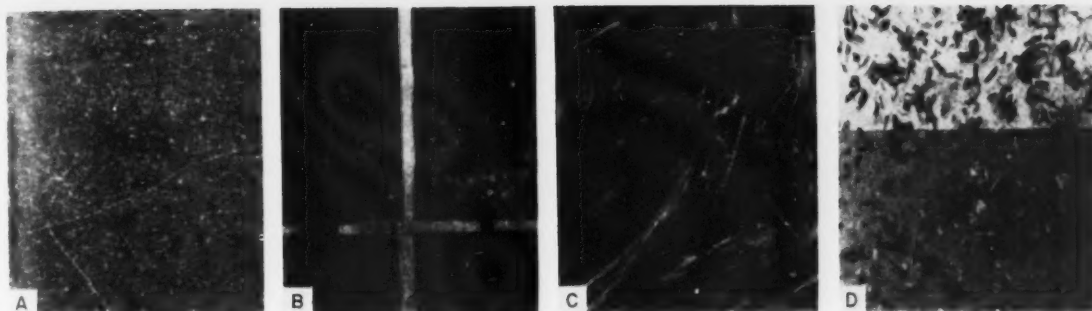
resistance is measured by means of a 500-v ohmmeter connected to 2 similar electrodes that simulate footwear and conductive rubber objects. A conductive floor should have a resistance low enough to prevent the buildup of dangerous static-charge voltages, yet its resistance should be high enough to prevent sparks or severe shocks from electric power lines or equipment that might become defective. According to NFPA, floors should have a resistance falling between 25,000 and 1,000,000 ohms when measured between specified electrodes that are 3 ft apart. The upper limit specified by NFPA provides a safety factor of more than 10, even under conditions of low humidity, if materials such as wool and plastics are prohibited.

In the Bureau's laboratory investigation, however, electrodes were spaced at 1-ft intervals—necessary because of the 18- by 18-in. sample size that was chosen for convenience in the experimental work. A preliminary study showed that this spacing would yield experimental results very close to those obtained from tests of an entire floor at an electrode spacing of 3 ft. Electrical tests were made under deliberately varied conditions of relative humidity and applied voltage. In addition to the laboratory tests on samples of flooring, field tests were made on five different types of conductive floors installed in hospitals in the Washington (D.C.) area.

Test Results

Results from studies of the influence of moisture and other factors showed that conductive floors should give satisfactory service in hospital operating rooms if certain precautions are observed. If oxychloride floors are used, the humidity of the air in the room in which they are installed should be controlled, and the cleaning schedule for the floor should be carefully established and maintained. Laboratory tests indicate that otherwise the electrical resistance of the floor may fall outside the accepted limits.

The durability and appearance of at least two of the available materials (linoleum and rubber) may depend on periodic waxing. Conductive waxes containing carbon black which do not deposit an insulating film are available, and should

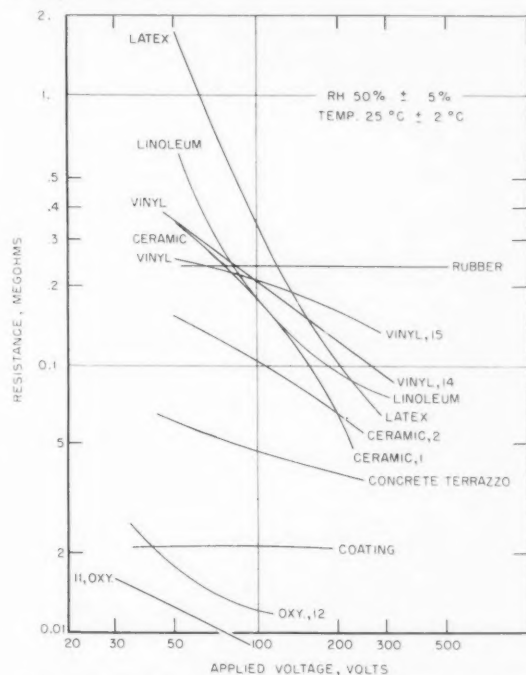


Samples from the pedestrian traffic ramp. Sample A (oxychloride) shows hairline cracks; B (ceramic) shows pitting in the mortar joints; C (rubber) exhibits extreme scuffing and scratching; and D (vinyl) shows extreme soiling of light-colored tiles.

be esthetically as well as electrically satisfactory on these uniformly black floors. Sealers should probably not be used on conductive floors until proven satisfactory by extensive electrical tests.

Electrostatic Tests

To substantiate the electrical test results, additional tests were carried out in which each type of floor was actually used to reunite electrostatic charges. Thus, a direct test was made of each flooring's effectiveness in eliminating static electricity hazards.



Effect of applied voltage on the electrical resistance of a number of floor tile materials. Resistance of sample is measured several seconds after a steady-state voltage is applied, in accordance with the National Fire Protection Association method No. 56.

There was excellent correlation between the electrical and electrostatic tests. For all but 2 of 12 specimens tested, peak voltage was less than 300 v when the resistance between 2 standard electrodes was less than 1,000,000 ohms. Conversely, the resistance was greater than 1,000,000 ohms when the voltage exceeded 300 v. Because this voltage is below the minimum sparking voltage in air, the specified 1,000,000-ohm limit with the standard electrodes was proven to be a reasonably valid criterion of the performance of these floors.

Nonelectrical Properties Studied

The nonelectrical properties studied were indentation, scratch resistance, slipperiness, scrubbing, water absorption, and stain resistance. Results of each study showed that the characteristics of the conductive materials are comparable to those of the corresponding nonconductive materials.

Of the properties studied, scratch resistance is probably the most important in hospital operating room floors for the sake of cleanliness as well as for ensuring good contact resistance. Two methods were used for measuring scratch resistance. In the first, a diamond point was moved across a flooring sample and the scratch width was measured. Loads on the diamond point were 250, 500, 750, and 1,000 g. In the second method, a pedestrian traffic test ramp was used to simulate actual flooring use. Photographs were made after 11 months (100,000 passages) and compared with photographs of unexposed flooring to determine the extent of scratching, smudging, and other damage.

¹ For further technical details, see *Conductive flooring for hospital operating rooms*, by Thomas H. Boone, Francis L. Hernach, Edgar H. MacArthur, and Rita C. McAuliff, J. Research NBS 63C, No. 2 (1959), also available as NBS Monograph 11. Price, 20 cents.

² Hazards from static electricity, NBS Tech. News Bul. 36, 82 (June, 1952).

³ Code for use of flammable anesthetics, (Safe practice for operating rooms), N.F.P.A. No. 56, National Fire Protection Association, 60 Battery-march Street, Boston, Mass.

GLASSMAKING has been practiced since ancient times. With the discovery that glass could be blown into any desired shape on the end of a pipe, glass became of commercial interest. Although glassmaking by hand has now given way to automatic mass production techniques, the development of new glasses still remains almost as empirical as it was in ancient times. Only recently have scientifically rigorous studies been made of the structure and properties of glass.

Thus, the fundamental nature of glass structure is still not clearly understood. A number of structural models have been proposed, but none of these models have been completely verified by experimental evidence. Indications are only that there is a short-range orderliness of structure. Not only this problem of structure but numerous others concerning the properties of glass are under study by many scientists today. With improved understanding of structure should come increased ability to design glasses having specified optical, mechanical, thermal, and chemical properties.

To provide the basic data needed for these studies, the Bureau has been conducting a program of fundamental research on the properties and structure of glass and glass-forming systems. This program, under the direction of C. H. Hahner, is concerned with the glass-forming process, the nature of the vitreous and supercooled states, viscosity and surface tension at elevated temperatures, the strength and elastic moduli over a wide range of temperatures, surface properties, and the bulk structure of glass. Other closely related investigations deal with the behavior of glass in unusual engineering applications, the development of special glasses for precision optical instruments, and standard glasses with closely measured physical properties. These items of current research are discussed in further detail below.

Interpretation of Glass Stability

Fundamental studies of glass-forming regions of simple ternary systems are providing an increased understanding of the nature of glass. For example, analysis of glass stability in terms of phase diagrams has shed additional light on the glass forming process and on the structure of multicomponent glasses. This work contributes to present glass theory by indicating that distinct chemical entities exist in glass. Of practical use as well is the related finding that stable glasses are usually found in areas of a phase diagram where the liquidus curve or surface is flat—an indication of a highly dissociated compound.

As stable glass formation is directly opposed to crystallization or devitrification, studies of glass stability include a determination of the factors affecting crystallization. One is the liquidus temperature—the highest temperature at which molten glass and the crystalline phase can coexist in equilibrium; another is the rate of crystal

Below: J. M. Nivert uses a cathetometer to read the mercury level in a dilatometer immersed in a thermostating bath. The device is used to measure thermal expansion of glass at and near room temperature.



growth at various temperatures; a third is the seeding or nucleation time required for crystal growth to start. A comparison of liquidus data with observed glass-forming ability provides a basis for structural interpretation.

Excess Entropy of Glass

Studies of the excess entropy of glass should also provide a better understanding of the vitreous state. Excess entropy is a measure of the greater molecular disorder of glass as compared with corresponding crystals of the same composition. Efforts are under way to measure this excess entropy in two ways on glasses for which stoichiometrically corresponding crystals also exist. One method is by direct measurements of specific heats over the temperature range from just above the melting point down as near as possible to absolute zero. The entropy loss thereby determined over this range for the glass, as compared with that for the crystal, gives values for the residual entropy. A precision low-temperature adiabatic calorimeter for part of these measurements is nearing completion. It will be supplemented with a high-temperature drop calorimeter. In the second method, vapor pressures are being measured as a function of tem-

RESEARCH

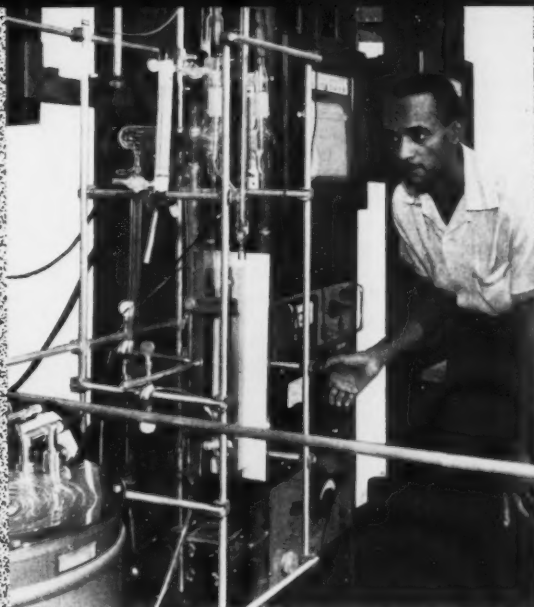


Above: Oscillating cup viscometer for measuring viscosity and surface tension of glass at temperatures above 2,000° C. W. Capps adjusts the vacuum system. In the upper foreground is the vacuum chamber, raised to show the induction heating coil surrounding the oscillating cup, and in the background is the high-frequency generator.

perature for substances in vitreous and crystalline states. The entropies of vaporization obtained from these measurements give values for the excess entropy of a particular specimen of glass. Such measurements on vitreous arsenic trioxide have led to interesting side-results indicating an extremely low condensation coefficient.

Glass Transition Temperature

As a criterion for the transformation between the vitreous and the supercooled liquid states, glass transition temperatures are being investigated. The effect of rate of temperature change on the volume-temperature curve is being measured for experimentally convenient glasses such as nitrate mixtures, selenium, and glucose, which have glass transformation temperatures in the vicinity of room temperature. Variations in rate of temperature change result in variations of transformation temperature of less than 6° C for a given composition. Measurements of glass transformation temperature as a function of com-



Above: C. Pearson adjusts an electrophoretic cell used in the study of the kinetics of the release of alkali from glass. The coulometric method used here determines the amount of alkali released.

position in two-component systems have suggested that certain systems form glasses only at stoichiometric ratios of the compounds, and a greater number form glasses at nonstoichiometric ratios.

Measured differences in thermal expansion coefficients for glass-forming substances above and below their glass transformation temperatures have been compared with values predicted theoretically from their viscosity-temperature relations. Results indicate that in most glasses, including silicates, the molecular structure may not change drastically with temperature in the transition region. However, in borate and nitrate glasses the thermal expansion data do not conflict with the concept of structural changes.

Transport Phenomena

The study of transport phenomena in vitreous silicates gives important information on both the bulk structure of glass and the structure of the surface domains. As many properties of glass are highly dependent upon the surface condition, this area of investigation promises to yield much information of both theoretical and practical value. Under study at the present time is the migration of mobile ions, such as alkali, through the glass under the influence of a concentration gradient created by subjecting a glass surface to water or other environments containing diffusion sinks for alkali. The experimental study of the diffusion kinetics is performed by a coulometric

method that simultaneously determines the amount of alkali released and removes any corrosion products, to maintain a constant pH. The data obtained are compared with mobility data derived from electrical conductivity measurements and analyzed with respect to various theoretical diffusion models. Of further interest are the details of the exchange-mechanism in this process; in particular, how the water constituents enter the structure of the glass. Methods are being developed not only to observe the kinetics of the net-diffusion process but also to obtain successive concentration profiles through the glass at various stages of the diffusion process.

High-Temperature Viscosity and Surface Tension

One phase of the study on the properties of glass is the development of methods for measuring viscosity and surface tension at temperatures up to 2,000° C. Such data on liquids at high temperatures are useful both for advance of production methods and for progress in fundamental scientific understanding. So far, a room-temperature model of an oscillating cup viscometer has

been designed and built. It has been calibrated at this temperature with oils of suitable viscosity. A high-temperature version is now under construction and will soon be completed. The apparent advantage of the oscillating cup viscometer for very high temperature work is that liquids under investigation can be in a totally enclosed container while the rest of the system is in a vacuum. Also, the cup containing the molten material is of a simple geometric shape so that it can be easily fabricated if frequent replacement is necessary. The first material scheduled for study is B_2O_3 .

Strength of Glass at Elevated Temperatures

Knowledge of the mechanical properties of glasses at elevated temperatures is necessary for aeronautical applications. The Bureau is measuring the modulus of rupture and the modulus of elasticity from room temperature to a temperature near the softening point of the glass. The study includes the effect of prolonged heating on the strength and on the rate at which samples of both annealed and tempered glass deform under

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load. Most of the work is being carried on at the Bureau with the close cooperation of the Materials Laboratory of the Wright Air Development Center and three glass companies: Libbey-Owens-Ford Glass Co., Corning Glass Works, and the Pittsburgh Plate Glass Co.

Only those glasses that are available in commercial quantities, or that have been produced in at least pilot-plant quantities in the form of polished plate, have been chosen for the study. Although the glasses selected for study are few in number they do cover a wide range of physical properties, particularly in respect to coefficient of expansion and strain point.

A study of test methods and methods of sample preparation has been completed. Strength tests on six types of glass-soda-lime-silica, 2 borosilicates, aluminosilicate, 96-percent silica, and fused silica—are almost complete.

Special Optical Glasses

The increasing use of infrared devices in the fields of target detection, fire control, missile guidance, and aerial reconnaissance creates a demand for improved optical materials for their construction. To develop multicomponent glasses having particular infrared transmission properties, the Bureau has been investigating the size, shape, and location of the glass-forming areas in the phase diagrams of simple two- and three-component systems. The physical and optical proper-



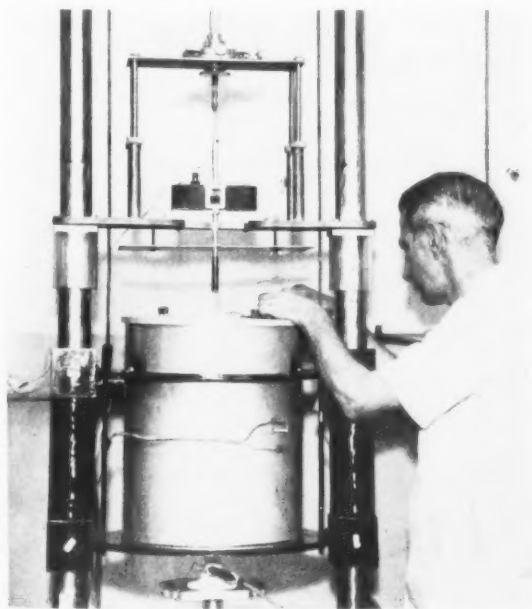
Portion of the glass research laboratory. D. Moore is preparing a sample of glass material for test in studies of the glassy state.

ties of the simple glasses can be correlated with composition to furnish clues to the atomic and molecular units composing the glass structure and their arrangement.

The effects of small amounts of water in the internal structure of glass have been largely neglected in the past. The presence of this water is strongly evident in the infrared spectra of practically all glasses. If glass is to serve as an infrared material at wavelengths beyond 2.75μ , means must be found to eliminate, or reduce, the water content. Work in this area has been in progress for some time. Glasses have been made in silicate, germanate, calcium aluminate, and tellurite systems, and many of their properties determined.

Multicomponent glasses based on the $\text{BaO-TiO}_2\text{-SiO}_2$ system have been made having good infrared transmittance, refractive indices up to 1.94, deformation points above 800°C , and excellent chemical durability. Similar germanate glasses have even higher refractive indices, transmit to somewhat longer wavelengths, deform above 700°C , and also have excellent chemical durability. Calcium aluminate glasses transmit to about 6μ except for a deep absorption band near 2.8μ . They have refractive index values of about 1.67 to 1.70, and deformation points near 750°C . However, they tend to devitrify easily and are attacked by moisture. The glasses based on TeO_2 have high values of refractive index, some of them being above 2.00. They deform at 350° to 400°C and have high coefficients of thermal expansion, which makes them sensitive to thermal shock. The glasses devitrify easily and evidently cannot be cooled in large amounts free of crystalline material.

Recently it has been found that the water band



Rotating cylinder viscometer for measuring the viscosity of glass at temperatures up to $1,450^\circ \text{C}$. A. Napolitano measures the viscosity of a soda-lime-silica glass as part of the program on standardizing measurements of glass properties.



High-temperature drop calorimeter used in studies of the excess entropy of glass. C. Pearson measures the vapor pressure of arsenic oxide in the crystalline and vitreous states to determine entropy of vaporization.

absorption is greatly reduced by the use of fluorides as an ingredient of the batches from which the glasses are melted. While the method has

been used only on a laboratory scale, it appears to be usable on melts of any size.

Standard Sample Program

The Bureau has for a number of years made available standard samples of glass to be used as checks on the accuracy of chemical analysis of glass. Two additional types of standard samples are now being considered. One will be a series of glasses, representative of important commercial types, that can be used to calibrate and standardize instruments for measuring the properties of glass. The second will be a series of high purity containing one, two, or three components. These glasses will be used to compare results between laboratories especially in studies of structure and constitution.

A soda-lime-silica glass which is representative of a widely used commercial composition is now being studied for use as a standard of viscosity and surface tension for molten glass. In the lower temperature range up to 1,450° C, a calibrated rotating-cylinder viscometer is used. The surface tension of this glass will also be determined over a similar temperature range. Additional types of glass, representative of those commercially available, will soon be obtained to extend the work on viscosity and surface tension calibrations as soon as the determinations on the soda-lime-silica glass are complete.

Bureau Supports Translation of Russian Journal

Measurement Techniques

THE National Bureau of Standards, in cooperation with the National Science Foundation, has been supporting the Instrument Society of America's program to translate important Soviet instrumentation and control journals.

The Bureau has transferred funds to the Foundation to support the first year of translation of the journal *Measurement Techniques* to provide American scientists and engineers with information on Russian activities in the measurement sciences. It is hoped that this initial support will enable the journal to become self-supporting on a subscription basis.

The first six numbers of the 1958 volume of the journal are now available from the Instrument Society of America, 313 Sixth Avenue, Pittsburgh 22, Pa. They contain a number of articles dealing with problems and instrumentation on linear measurement, mechanical measurement, electrical measurement, and radio measurement, in addition to reviews, essays, and discussions of the Committee of Standards, Measures, and Measuring Instruments of the Soviet Union.

Subscription prices per year (6 issues):

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Libraries of nonprofit academic institutions:	
United States and Canada	10.00
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Single issues to everyone, each	6.00

Measurement of Lens Distortion

THE BUREAU, in work partly supported by the U.S. Air Force, has completed an evaluation of four separate methods for measuring distortion in photogrammetric lenses. Recent studies show that both an inverse nodal slide and a modified goniometric method give values that are precise to within $\pm 3 \mu$ for lenses whose tolerance limits are $\pm 20 \mu$.¹ Similar accuracy was achieved in an earlier study of a nodal slide bench and a precision lens-testing camera.² Provided proper care is exercised in making the measurements, each of the four methods may be relied upon to predict lens performance, or to verify the accuracy of any of the other methods.

Today the process of mapping large areas by aerial photographic means is being used more and more for purposes such as soil conservation, forestry studies, crop and flood control, and highway planning. Since this type of mapping was first introduced, the radial distortion in the focal plane of photogrammetric lenses has been intensively studied. The magnitude of the distortion is a measure of the degree of accuracy of reproduction of the photographed scene.

Lenses consequently are being developed to give ever-decreasing values for distortion, in order to increase the reliability of the measurements made from aerial photographs. Hence, methods are continuously being refined for determining these values. The present work was undertaken by F. E. Washer and W. R. Darling of the optical instruments laboratory, to investigate two of the newer methods presently employed, the inverse nodal slide and the modified goniometric method.

In using the inverse nodal slide, an illuminated

reticle is placed at the rear focal point of the lens under test, and measurements are made in the emergent collimated beam with an angle-measuring telescope. Distortion values are computed from the measured change in direction of the beam from the direction predicted for a distortion-free lens. Movement of the telescope across the beam provides a means for determining quantitatively the effect of asymmetric use of aperture. Thus the inverse method may be used to check this source of error in other methods.

The modified goniometric procedure employs a viewing theodolite and a calibrated linear scale, with the lens under test mounted on a bench between them. Distortion is measured by determining the angular relationships that obtain when the theodolite is pointed through the lens toward selected graduations on the scale. To cover the entire range of the scale, the theodolite is displaced transversely. Errors arising from asymmetric use of aperture are corrected by displacing the theodolite for each setting in such a manner that the exit aperture of the lens appears centered in the exit pupil of the theodolite.

In these experiments, the lens tested had a focal length of 150 mm, with values of distortion referred to the calibrated focal length ranging from $+110$ to -110μ . In comparing the values of distortion found by the two methods, all values were referred to the calibrated focal length. Thus the maximum positive value in each case was equal in magnitude to the maximum negative value.

After various sources of error had been isolated and either eliminated or compensated for, nearly identical values of distortion were obtained with both methods. An intercomparison with the two procedures previously investigated showed that when proper caution is observed the values obtained by any one method need not depart from the common average of all the methods by more than $\pm 5 \mu$.

During the course of the experiments it was found that values derived by both the inverse nodal slide and the modified goniometric method were adversely affected by errors in angle, curvature of bench ways, and asymmetric use of aperture.

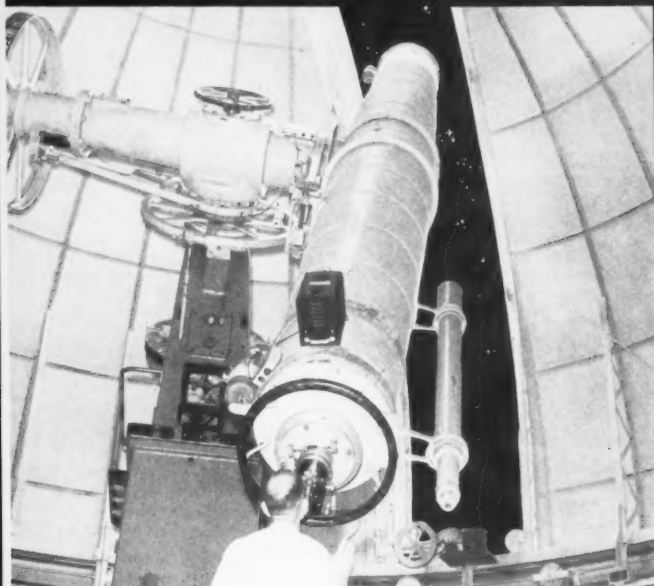


W. R. Darling adjusts apparatus developed to measure lens distortion by the inverse nodal slide method. Mounted on a T-bench, left to right, are telescope, pentaprism, lens under test, illuminated reticle, and light source.

¹ For further technical details see the following papers by F. E. Washer and W. R. Darling: Evaluation of lens distortion by the inverse nodal slide, *J. Research NBS* 63C, 105 (1959); Evaluation of lens distortion by the modified goniometric method, *J. Research NBS* 63C, 113 (1959).

² Evaluation of lens distortion by visual and photographic methods, by F. E. Washer, W. P. Tayman, and W. R. Darling, *J. Research NBS* 61, 509 (1958); and Evaluating lens distortion: two methods compared, *NBS Tech. Notes* 43, 47 (1959).

INVERTING INTERFEROMETER for STELLAR STUDIES



The recently designed astronomical interferometer is used to determine aberrations in the 26-in. telescope at the Naval Observatory.

THE BUREAU has developed an interferometer which shows promise as a simple, accurate, convenient-to-use instrument for astronomical research. This interferometer, devised by J. B. Saunders, consists of a double-image prism and a telescope objective. With this combination, the separation, the diameters, and the time of meridional transit of stars can be accurately measured. In addition, the instrument provides a means of checking on aberrations in astronomical objectives, both reflectors and refractors.

The use of interferometry in astronomy has been greatly limited by the low luminosity of the light sources involved (the star or stars under observation) and the complexity of interferometric devices developed for stellar observations. For example, measurements with one such instrument, the Michelson stellar interferometer, are based on variations in the contrast of interference fringes appearing in the focal plane of the lens. As atmospheric conditions affect contrast markedly, this device is unsuitable for any but ideal viewing conditions. Another interferometer, the Mach-Zehnder instrument, is more practical, but its complexity is a deterrent to general use. The instrument developed by the Bureau, on the other

hand, is both easy to operate and much less dependent upon atmospheric conditions.

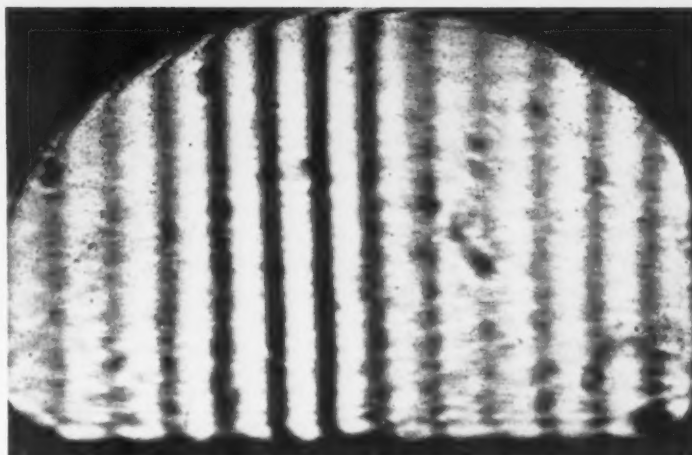
The Bureau's instrument is a *wavefront-inverting* interferometer. This optical property is introduced by the nature of the prism used—a modified Koesters prism consisting of two identical prisms cemented together with a partially reflecting film on the inner face.¹ The fringes produced by this device can be viewed from either side of the prism. From either side, a segment of the objective appears to be folded over onto the remaining part. If the objective is bisected by the dividing plane of the prism, fringes occupy exactly half the lens area. If it is bisected off center, only the overlapping area contains fringes and the remaining portion is interference free.

The fringes are pivoted to the dividing plane so that any motion due to atmospheric effects does not affect the position of fringes along one margin of the field. This property provides a degree of stability that almost suppresses vibration effects. Another advantage is the permanent position of the bound end of the zero order or darkest fringe.



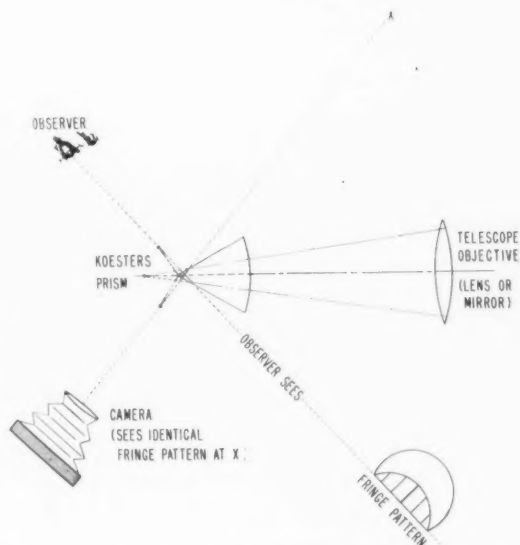
The stellar interferometer with a camera attachment replaces the eyepiece of a large telescope at the Naval Observatory. J. B. Saunders of the Bureau staff simultaneously observes and photographs fringes to test the quality of the telescope's 26-in. objective.

Typical fringe pattern obtained with the wavefront-inverting interferometer. Here the objective is bisected by the dividing plane of the prism so fringes occupy exactly half the lens. These fringes are pivoted to the dividing plane and so are relatively free from mechanical vibration effects. Furthermore, the zero-order or darkest fringe is permanently "frozen" in the center, eliminating searching.



This fringe is "frozen" in the center of the prism during construction, so that the searching usually required in interferometric observations is eliminated.

The prism is mounted together with a specially designed eyepiece and a camera to form a compact astronomical instrument. When it is attached to a telescope in place of the regular eyepiece, this arrangement permits fringes to be observed and photographed simultaneously.



The essential optics of the wavefront-inverting interferometer.

In using this instrument to measure the angular separation of two light sources, such as a double star, two sets of fringes are obtained. Each source produces its own set and the angle between the two sets is an accurate measurement of the separation of the stars.

The described arrangement can also be applied to the measurement of the angular width of stars. This width is a function of the distance from the dividing plane, where the two sets of fringes are always motionless, to the plane where they fade out completely. If this distance is designated by h , the angular diameter α is given by the formula $\alpha = \lambda/4h$, where λ is the mean wavelength of the light.

To use the instrument to measure the time of meridional transit of stars, it is adjusted so that the two interfering beams suffer an intensity reversal when the star crosses the meridional plane. A photoelectric unit indicates the exact transit time—the moment when the intensities of the two beams are equal.

Finally the curvature or shape of the fringes is a measure of the shape of the wavefront. Consequently, it is also a measure of the aberrations of the telescope objective. The Bureau found that very large astronomical objectives, reflectors and refractors, can be easily tested while they are pointed at a star, if atmospheric conditions are suitable. Photographs have been taken of the fringes produced by the 26-in. telescope at the Naval Observatory in Washington (D.C.).

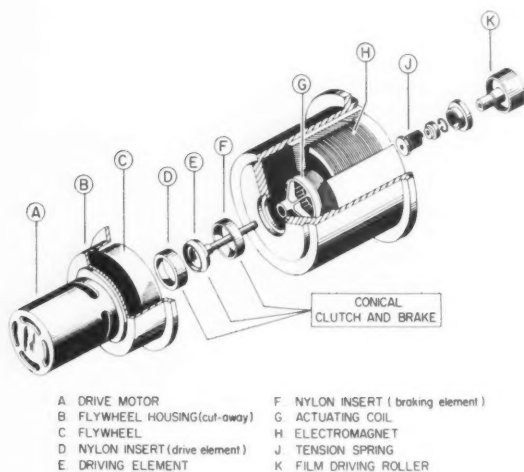
¹ The Koesters interferometer, by J. B. Saunders, *J. Research NBS* 58, 27 (1959) RP27:30

Intermittent-Action Camera

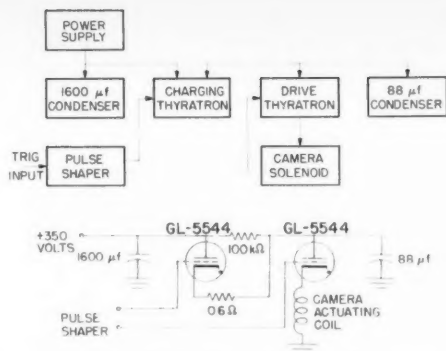
THE BUREAU has developed a recording system that simultaneously photographs randomly occurring events displayed on an oscilloscope screen and the precise time of each event. The camera was developed by G. Hefley, R. H. Doherty, and E. L. Berger of the Boulder (Colo.) Laboratories as part of a program to record and study the electromagnetic radiation from lightning strokes (sferics) that is propagated over long distances.

Because a picture is taken only when the camera is triggered by the event to be photographed, film consumption is reduced considerably as compared with a continuously operating camera. When the standard time broadcasts of NBS station WWV are used to synchronize the system, the absolute accuracy is dependent only on the propagation variables of the WWV signal. Cycling time of one complete operation is 7 msec.

Studies of intermittent, randomly occurring events such as sferics require photographic recording instruments of a special type. Making continuous photographic records of oscilloscope waveforms is ordinarily the method used to make these records, but it is impractical for long periods of time with strip cameras because of excessive film consumption. Moreover, the commercially available framing cameras usually do not attain framing rates great enough for certain sferic observations. Frequently, it is necessary to combine the photographic data with some form of accurate time presentation so that sferics observed at widely separated stations can be identified on a world-time basis and the time interval between sferics can be measured precisely. The intermittent-action camera provides these advantages.



Exploded view of high-speed clutch used in intermittent-action camera.



Circuit that controls camera equipment to photograph randomly occurring events displayed on an oscilloscope screen.

The rapid framing rate of the camera results from the use of a high-speed clutch between the film drive and a continuously revolving flywheel. The clutch actuation mechanism is similar to a large electrodynamic speaker. When a pulse triggered by the signal is applied to the clutch part corresponding to the voice coil, a cone is driven into engagement with the flywheel and rotates a small drum in contact with the film. The length of the pulse is timed so that the rotation of the drum pulls exactly one frame of film past the lens opening.

The peak power applied to the voice coil is approximately 35 kw. Power surges of this magnitude may be repeated at intervals of only a few milliseconds by utilizing two condenser reservoirs and two thyatrons in a series arrangement. An 88- μ f condenser is discharged through the voice coil by one thyatron and after a short delay is recharged from a 1,600- μ f reservoir by the other thyatron. Consequently, the power supply required to operate the system need only provide an average current sufficient to maintain the charge on the large condenser reservoir at the maximum duty cycle.

The time of the event is displayed by an array of small neon bulbs that indicate, in binary fashion, numbers that correspond to the hour and date. The bulbs are illuminated by a pulse of 100- μ sec duration. The timing circuit consists of conventional decimal-counting units arranged to count from 10 μ sec to 31 days with the count controlled by a precision 100-ke standard. Each decimal-counting unit has a binary output that is read out by the same pulse used to trigger the camera. To prevent any ambiguity in the read-out, should the binary output happen to be changing state, the time of the read-out is controlled by the timer. The read-out is made by the first 100- μ sec pulse following the event to be recorded. Smaller increments of time are resolved by time markers on an oscilloscope trace separated from the signal display trace.

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Section D. Radio Propagation, Volume 64D, No. 2, March-April 1960.

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Terrestrial propagation of very-low-frequency radio-waves, a theoretical investigation, J. R. Wait.

Aurora of October 22/23, 1958, at Rapid City, South Dakota, F. E. Roach and E. Marovich.

Technical News Bulletin, Volume 44, No. 3, March 1960. 15 cents. Annual subscription \$1.50, 75 cents additional for foreign mailing.

Basic Radio Propagation Predictions for May 1960. Three months in advance. CRPL-D186. Issued February 1960. 15 cents. Annual subscription \$1.50, 50 cents additional for foreign mailing.

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Distribution of incoming lettermail at the Baltimore, Maryland City Post Office, B. M. Levin and A. E. Newman, NBS Tech. Note 33 (PB151392) (1959) \$2.50.

Application of RF micropotentiometers for calibration of signal generators to 1000 Mc, L. F. Behrent, NBS Tech. Note 37 (PB151396) (1960) 50 cents.

Design and construction of a liquid hydrogen temperature refrigeration system, D. B. Chelton, J. W. Dean, and B. W. Birmingham, NBS Tech. Note 38 (PB151397) (1960) 75 cents.

Helium refrigeration and liquefaction using a liquid hydrogen refrigerator for precooling, D. B. Chelton, J. W. Dean and T. R. Strohbridge, NBS Tech. Note 39 (PB151398) (1960) 50 cents.

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TECHNICAL
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FREDERICK H. MUELLER, *Secretary*

NATIONAL BUREAU OF STANDARDS

A. V. ASTIN, *Director*

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- 2,911,573 November 3, 1959. Multiple point altimeter for use with toss bombing integrators. Jacob Rabinow and William B. McLean (Navy).
- 2,911,911 November 10, 1959. Antifriction gascheck wads. Hobart S. White.
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- 2,913,008 November 17, 1959. Nonlinear sensitive diaphragm. Fidel Cordero.
- 2,913,524 November 17, 1959. Loudspeaking interoffice telephone. George Franklin Montgomery.
- 2,913,600 November 17, 1959. Diode amplifier and computer circuitry. James A. Cunningham and Arthur W. Holt.
- 2,913,706 November 17, 1959. Transcriber selection circuit for magnetic drum memory. Ragnar Thorensen and Biagio F. Ambrosio.
- 2,914,993 December 1, 1959. Tool shaping machine. Carl E. Pelander (Army).
- 2,915,364 December 1, 1959. Preparation of pure titanium tetrachloride. Wilbur S. Clabaugh and Raleigh Gilchrist (Navy).
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